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Robustness, Diagnostics, Computing & Graphics in Statistics

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DAAL03-89-G-0026

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Willard Miller, Jr.

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Univ. of Minnesota
Minneapolis, MN 55455

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13. ABSTRACT (Maximum 200 words)

The workshop on robustness, diagnostics, computing and graphics in statistics was held on July 21, 1989 - August 12, 1989. Robustness, Diagnostics volumes 1 and 2 will appear in IMA Volumes in Mathematics and its Applications, Springer-Verlag, New York. Computing and Graphics in Statistics will appear in IMA volumes in Mathematics and its Applications, Springer-Verlag, New York.

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ARO 26717.1-MA-CF

INSTITUTE FOR MATHEMATICS AND ITS APPLICATIONS

FINAL REPORT TO ARO

(1) CONTRACT OR GRANT NUMBER: DAAL03-89-G-0026

(2) PERIOD COVERED BY REPORT: July 1, 1989 – March 31, 1989

(3) TITLE OF PROPOSAL: ROBUSTNESS, DIAGNOSTICS, COMPUTING & GRAPHICS IN STATISTICS

(4) NAME OF INSTITUTION: University of Minnesota, Minneapolis

(5) AUTHOR OF REPORT: Willard Miller, Jr.

(6) WORKSHOPS SUPPORTED:

Robustness, Diagnostics, Computing & Graphics in Statistics (see attached program for detailed information)

(A) *Robustness, Diagnostics* volumes 1 and 2, to appear in IMA Volumes in Mathematics and its Applications, Springer-Verlag, New York. (in progress, copies will be sent to the Air Force Office of Scientific Research, when available)

(B) *Computing and Graphics in Statistics*, to appear in IMA Volumes in Mathematics and its Applications, Springer-Verlag, New York. (in progress, copies will be sent to the Air Force Office of Scientific Research, when available)

May 23, 1990

ROBUSTNESS, DIAGNOSTICS, COMPUTING AND GRAPHICS IN STATISTICS

JULY 21, 1989 – AUGUST 12, 1989

List of papers to appear (to date) in the Volumes:

ROBUSTNESS, DIAGNOSTICS AND COMPUTING IN STATISTICS

(Two volumes)

Volume 1:

AUTHOR	Title
M. Akritas and Y. Zubovic	"Survey of robust procedures for survival data"
A.C. Atkinson and S. Weisberg	"Simulated Annealing for the Detection of Multiple Outliers Using Least Squares and Least Median of Squares Fitting"
J. Beran and S. Ghosh	"Goodness of Fit Tests and Long-Range Dependence"
G. Boente and R. Fraiman	"A Functional Approach to Robust Nonparametric Regression"
C. Field and E. Ronchetti	"An Overview of Small Sample Asymptotics"
T. Hettmasperger and J. Naranjo	"Some Research Directions in Rank-Based Inference"
H. Lopuhaä	"Breakdown Point and Asymptotic Properties of Multivariate S-Estimators and τ-Estimators: A Summary"
Alfio Marazzi	" Algorithms and Programs for Robust Linear Regression"
M. Markatou and E. Ronchetti	"Robust Testing Procedures for Linear Models: An Overview"
R. Maronna and V. Yohai	"Recent Results on Bias-Robust Regression Estimates"
J. McKean and S. Sheather	"Small Sample Properties of Robust Analyses of Linear Models Based on R-Estimates: A Survey"
L. Molinari and G. Dumermuth	"Robust multivariate spectral analysis of the EEG"
S. Morgenthaler	"Configural Polysampling"
N. Neykov and P. Neytchev	"*Unmasking multivariate and leverage points by* means of BMDP3R"
S. Portnoy	"Regression Quantile Diagnostics for Multiple Outliers"
H. Rieder	"Robust Testing of Functionals"
P. Rousseeuw and G. Bassett	"Robustness of the p-subset Algorithm for Regression with High Breakdown Point"
P. Rousseeuw and B. van Zomeren	"Robustness Distances: Simulations and Cutoff Values"
D. Tyler	"Some issues in the Robust Estimation of Multivariate Location and Scatter"
J. Tukey	"Graphical displays for alternate regressions fits"
H. White	"Adaptive Generalized Least Squares with Dependent Observations"

Volume 2:

AUTHOR	Title
R.D. Cook and S. Weisberg	"Regression Diagnostics: Robust *versus* Least Squares Residuals"
S. Geisser	"Diagnostics, Divergences and Perturbation Analysis"
P. Huber	"Between Robustness and Diagnostics"
A.J. Lawrance	"Local and Deletion Influence"
J. Ledolter	"Outliers in Time Series Analysis Some Comments on their Impact and their Detection"
J. McKean, S. Sheather and T. Hettmansperger	"Regression Diagnostics for Rank-Based Methods II"
M. Obrien	"GLIMPSE: An Assessor of GLM Misspecification"
R. Schall and T. Dunne	"Diagnostics for Regression-Arma Time Series"
J. Simonoff	"General Approaches to Stepwise Identification of Unusual Values in Data Analysis"
Chih-Ling Tsai	"Comparisons Between First Order and Second Order Approximations in Regression Diagnostics"

STATISTICAL COMPUTATION AND STATISTICAL GRAPHICS
(One volume)

AUTHOR	Title
W. DuMouchel & F. O'Brien	"Integrating A Robust Option into a Multiple Regression Computing Environment"
D. Grier	"Algorithm Development for Nonstandard Least Squares Problems. Repeated Categorical Responses with Missing Values: A Case Study"
T. Hesterberg	"Importance Sampling for Bayesian Estimation"
C.B. Hurley & R.W. Oldford	"A Software Model for Statistical Graphics"
J. McDonald & J. Pedersen	"Geometric Abstractions for Constrained Optimization of Layouts"
J. Nelder	"Glimpse, A Knowledge-Based Front End for Glim"
J. Pedersen	"Situations, Summaries and Model Objects"
D. Scott	"On Estimation and Visualization of Higher Dimensional Surfaces"
J. Miller & E. Wegman	"Construction of Line Densities for Parallel Coordinate Plots"
L. Wilkinson	"Algorithms for Choosing the Domain and Range when Plotting a Function"
F. Young & J. Smith	"Towards a Structured Data Analysis Environment: A Cognition-Based Design"
F. Young & P. Rheingans	"Visualizing Structure in High-Dimensional Multivariate Data"

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IMA NEWSLETTER #149

October 30 - November 17, 1989

1989-90 Program
DYNAMICAL SYSTEMS AND THEIR APPLICATIONS

NEWS AND NOTES

Motorola Joins IMA Participating Corporations

Motorola became an IMA Participating Corporation, effective October 16. This brings the number of PC's to 9.

Workshop on DYNAMICAL ISSUES IN COMBUSTION THEORY

November 13–17, 1989
Organizers: S.-N. Chow, P. Fife, M. Golubitsky,
Amable Liñán, R. McGehee, G. R. Sell and F. Williams

The aim of the workshop is to cross fertilize research groups working in topics of current interest in combustion dynamics and mathematical methods applicable thereto.

Specific topics to be covered include: detonation instabilities, renormalization methods, complex chemistry, flame front instabilities, dynamics of diffusion flames, pattern formation in combustion, and ignition events.

The lectures will be held in Conference Hall 3-180 on the entry floor of the new Electrical Engineering/Computer Science Building. This building is located on the corner of Washington Avenue and Union Street, a block from the IMA Main Office. The conference hall is on the Ethernet and has a projection system for display of computer output.

The detailed Workshop schedule, and the regular IMA program, can be found in the pages to follow.

PARTICIPATING INSTITUTIONS:Georgia Institute of Technology, Indiana University, Iowa State University, Michigan State University, Northern Illinois University, Northwestern University, Ohio State University, Purdue University, University of Chicago, University of Cincinnati, University of Houston, University of Illinois (Chicago), University of Illinois (Urbana), University of Iowa, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, Wayne State University
PARTICIPATING CORPORATIONS:Bellcore, Cray Research, Eastman Kodak, General Motors, Honeywell, IBM, Motorola, 3M, UNISYS

Workshop on
DYNAMICAL ISSUES IN COMBUSTION THEORY

November 13–17, 1989
Organizers: S.-N. Chow, P. Fife, M. Golubitsky,
Amable Liñán, R. McGehee, G. R. Sell and F. Williams

Monday, November 13

The scheduled talks today are in Conference Hall EE/CS 3-180

9:00 am	**Registration and coffee hour**	Reception Room EE/CS 3-176
9:30 am	**J.W. Dold** University of Bristol	Asymptotic laminar triple-flamelet structures in non-premixed turbulence

Abstract: A laminar triple-flamelet in strained and sheared flow is taken to represent the local structure of the end of a turbulent diffusion flame that has been extinguished (usually by the flow) in some region but not in another. The most important feature of such a flamelet is its ability to propagate. This greatly enriches the usual one-dimensional picture of an infinite laminar diffusion flamelet in uniformly strained flow that extinguishes everywhere at some critical strain-rate $\sigma = \sigma_c$. Purely asymptotic arguments, based on a large Zeldovich number $\beta \gg 1$, show that the triple-flamelet reaches an infinite negative propagation speed (propagation of an extinction front) at this strain-rate. The propagation speed only becomes positive (and much slower) below a relatively small strain-rate $\sigma < \sigma_0 = O(\sigma_c/\beta)$. Thus a turbulent diffusion flame that is punctured at some moment, by having $\sigma > \sigma_c$ locally, pops like a balloon—a hole rapidly opens throughout the region in which $\sigma > \sigma_0$ on the diffusion flame.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**David Wagner** University of Houston	Detonation and deflagration wave solutions to reacting compressible Navier Stokes equations

Abstract: This lecture concerns the existence and behavior of detonation and deflagration wave solutions to reacting compressible Navier Stokes equations, and various special limits of these solutions (ZND, high activation energy, etc .).

2:00 pm	**D.S. Stewart** University of Illinois, Urbana	Discrete modeling of beds of propellant subjected to strong stimulus

Abstract: This talk describes a theoretical investigation of violent burning processes in beds of propellant when subjected to strong stimulus. The point of view taken will consider the discrete character of the bed and calculate and experimentally characterize the particle-particle interactions within the bed. A principal goal is to find the propagation and failure mechanism for the propagation of a self-sustaining reactive wave. The motivation for the research is to aid in the design of low vulnerability propellant. As far as possible, quantities in the theory and experiment will relate directly to the properties of the propellant that can be changed in the manufacturing process.
The structure of the theory leads to recursion relations which predict certain dynamics and the stability of certain steady states within the context of these recursion relations will be discussed.

4:00 pm	**Vincent Hall 502** (The IMA Lounge)	IMA Tea (and more!)

Tuesday, November 14

The scheduled talks today are in Conference Hall EE/CS 3-180

9:30 am	**Rupert Klein** Princeton University	On the dynamics of weakly curved detonations

Abstract: Extensive experimental evidence from studies of gaseous explosions and condensed phase combustion calls for a theoretical description of the dynamics of curved shock-reaction waves. Typical radii of curvature of such fronts are large compared to an average reaction zone thickness. This implies weak surface curvature on the reaction zone length scale and allows an approach using the tool of asymptotic expansions.

We first consider diverging waves evolving on the timescale given by Huyghens' principle for a front moving at nearly the Chapman-Jouguet velocity. The ansatz of a quasi steady and quasi-onedimensional reaction zone structure yields an Eigenvalue problem for the front normal speed D parametrized by the local mean surface curvature κ. Its solution provides a relation $D = D(\kappa)$ which determines the evolution of the front given appropriate initial data. We emphasize the crucial influence of the chemical model on the curvature-speed relation and, in particular, address the effect of backward reactions.

The quasisteady theory fails for focussing waves, i.e. for negative curvature. An inherently unsteady wave acceleration occurs and two potential limit situations must be distinguished. The wave either retains its quasi-onedimensional structure but quickly leaves the near-CJ regime, or transverse pressure gradients eventually enforce nonnegligible tangential flow divergence so that multidimensional effects enter the picture, still under near-CJ conditions. For both cases, we outline the modifications needed to maintain asymptotic description.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Amable Liñán** Madrid	Ignition fronts of diffusion planes
2:00 pm	**B. Larrouturou** INRIA	On some mathematical results on planar and curved premixed flames

Abstract: We present a set of rigorous mathematical results obtained in collaboration with several colleagues (H. Berestycki, R. Ferretti, J.M. Roquejoffre) concerning the propagation of planar or curved flames in an infinite cylindrical tube.

We first consider planar flames in the framework of the isobaric approximation, and investigate in detail the behaviour of unsteady solutions when the reaction term is initially small but non zero in the fresh gases; in other words, we present a rigorous analysis of the well-known cold boundary difficulty.

Then, we present some error estimates for bounded domain approximations of the planar traveling front solutions; these estimates are of interest for the numerical approximation of these solutions.

Lastly, we consider curved flames in the framework of the constant-density (thermo-diffusive) approximation, in the presence of a non uniform velocity field, and present mathematical results for both cases of a unit Lewis number and of a non unit Lewis number.

Wednesday, November 15

All scheduled talks today are in Conference Hall EE/CS 3-180

9:30 pm	**Martine Marion** Ecole Centrale de Lyon	Attractors and turbulence for some models of combustion

Abstract: There is a close relationship between the number of degrees of freedom describing fluid flow and the fractal dimension of the Navier-Stokes attractor. Hence studying attractors leads to a new insight in turbulence theory.

The aim of this lecture is to extend this approach to some models of combustion. We consider two problems: a model in incompressible fluid with a Boussinesq approximation and a model in solid combustion. We prove the existence of a universal attractor and derive estimates of its dimension.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**Bernard J. Matkowsky** Northwestern University	Bifurcation, pattern formation and chaos in combustion

Abstract: We employ analytical and numerical methods to describe solutions of both gaseous and solid fuel (condensed phase) combustion.

In gaseous fuel combustion we consider a flame stabilized on a line source of fuel. A basic solution describes a smooth cylindrical flame front, separating burned from unburned gases. By varying critical parameters of the problem, we construct additional solutions on branches which bifurcate from the basic solution. These solutions exhibit both spatial and temporal patterns, which become more and more complex as the distance from the bifurcation point is increased. They describe e.g. (i) cylindrical flames which oscillate (both sinusoidal and relaxation oscillations) about a mean position given by the stationary cylindrical flame front, (ii) stationary cellular flames, and (iii) oscillatory cellular flames, which describe both traveling waves about, and standing waves about, and standing waves on the cylindrical front.

In condensed phase combustion we consider a reaction fron (so-called solid flame) propagating through a cylindrical sample. Such problems describe the process of self propagating high temperature synthesis (SHS). Ignition of a cylindrical sample at one end, sends a thermal wave through the sample, converting unburned reactants to solid products. We describe various modes of propagation, which have been experimentally observed, as bifurcations from a basic solution corresponding to a uniformly propagating planar front. These include (i) oscillatory combustion - in which a planar front propagates with an oscillatory velocity, (ii) spinning combustion - in which a hot spot (or spots) moves in a helical fashion along the surface of the sample, and (iii) multiple point combustion - in which the hot spot appears, disappears, and reappears repeatedly. Finally we predict additional modes of propagation, including intermittent and chaotic combustion, exhibiting yet more complex behavior, which have not yet been experimentally observed.

2:00 pm	**Michael Gorman** University of Houston	Periodicities and deterministic chaos in laminar premixed flames

Abstract: Our experiments on flat, laminar premixed flames have been conducted on circular, square, annular and linear burners housed in a glass chamber in which the ambient pressure can be controlled. Some of the dynamic modes of flame front propagation we have found are: For a circular burner, an axial mode in which the entire flame front moves alont the axis perpendicular to the burner surface, a radial mode in which the flame front changes its radial extent, a drumhead mode in which parts of the flame front vibrate perpendicular to the burner surface (with some modes having spatial characteristics similar to those of a circular drumhead), a doubly periodic spiral mode in which the flame front is a point which moves as a rotating spiral and a pinwheel mode in which the flame front becomes 3 luminous spots which rotate around the center of the burner like a pinwheel. In another region of parameter space the flame front physically flutes forming cusps and folds which demark the boundaries of cells. In this talk we will show that both pulsating flames and cellular flames have nonperiodic modes of propagation which are described by deterministic chaos. We will present measurements of the spatial and temporal properties of the periodic and the chaotic states. We will show videotape of all these modes.

3:00 pm	**Victor Roytburd** Rensselaer Polytechnic Institute	Dynamics of unstable detonations: Numerics and asymptotics

Abstract: In a broad range of regimes traveling detonation waves develop instabilities – pulsating instabilities in case of one-dimensional waves. A highly efficient numerical method has been recently applied for the direct simulation of this phenomenon. We discuss this method involving front tracking and adaptive mesh refinement. We compare the method with other methods on the test problem of unstable detonations. Numerical results reveal a very interesting dynamic behavior which can be interpreted in the framework of an asymptotic theory. The results are obtained in a joint work with A. Bourlioux and A. Majda.

Thursday, November 16

The morning talks today are in Conference Hall EE/CS 3-180

9:30 am — **Michael Frankel**, Indiana U.-Purdue U. — On surface dynamics generated by free boundary problems associated with combustion

Abstract: We introduce a number of free boundary problems whose boundary dynamics mimics that of flame fronts, and generates either cellular-chaotic or oscillatory-spinning behavior. The behavior of free boundaries can be modeled by coordinate-free surface dynamics equations expressed in terms of local geometrical characteristics. The desirability of numerical and rigorous study of these models is discussed.

10:30 am — Coffee break — Reception Room EE/CS 3-176

11:00 am — **M. R. Baer**, Sandia National Labs. — Reactive waves in granulated energetic materials

Abstract: The combustion of granulated energetic materials, such as porous explosives or damaged propellants, involves the coupling of a variety of thermal, chemical and mechanical processes. Accelerated combustion is greatly influenced by the granular microstructure, and combustion-induced compaction preconditions the granular reactant prior to the onset of flame spread. It is now known that this mechanical process is the key that links the modes of multiphase combustion from deflagration to detonation.

Guided by experimental observations, we have developed a multiphase mixture model to describe flame spread and the growth to detonation in granular materials. This description treats each phase as fully compressible and in thermodynamic nonequilibrium. Model closure is achieved using a rate-dependent evolution description of solid volume fraction. Since the treatment of volume fraction as an independent kinematic variable has not been well studied, we focus on dynamic compaction issues.

We will describe our studies of compaction waves and discuss model improvements motivated by recent experiments. Numerical calculations of low-velocity impact experiments reveal details of compaction and combustion waves near the threshold of deflagration-to-detonation transition (DDT).

We then present a study of the mathematical structure of the reactive multiphase equations. A characteristics analysis has revealed the hyperbolic nature of the field equations when dissipative effects are neglected. Sonic conditions appear as singularities in this wave description when characteristics coalesce. Pore collapse during dynamic compaction may play a critical role in producing these sonic flow conditions.

2:00 pm — **John D. Buckmaster**, University of Illinois, Urbana — Activation energy asymptotics and detonation stability

Abstract: Activation energy asymptotics has proven to be of enormous value in unraveling the mysteries of low Mach number combustion. It has been applied to the problem of detonation stability (a high Mach number application) with mixed results. These will be reviewed.

This talk will be held in Conference Hall EE/CS 3-180

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Joint School of Mathematics Colloquium/IMA talk

3:15 pm — **Andrew Majda**, Princeton University — Unstable detonations and dynamic homogenization for condensed phases

This talk will be held in Vincent Hall 16.

Tea will be served at 2:55 pm in the Mathematics Commons Room Vincent Hall 120.

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WORKSHOP BANQUET

A buffet dinner will be held at the Campus Club, Coffman Union. Wine-and-cheese starts at 5:45 pm and dinner at 6:30 pm. Details about signing up for the dinner will be disseminated at the Workshop. The banquet speaker is D. R. Kassoy.

approx. 7:30 pm	**David R. Kassoy** University of Colorado, Boulder	Confessions of the singularly perturbed professor

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Friday, November 17

All scheduled talks today are in Conference Hall EE/CS 3-180

9:30 am	**F.A. Williams** UC San Diego	Reduced kinetic mechanisms for complex combustion chemistry

Abstract: Recent studies by asymptotic methods are considered, in which complex chemistry involving hundreds of elementary steps is reduced systematically to a few steps that can be used for calculating flame structures. Revisions in structures of premixed flames and diffusion flames, implied by the reduced mechanisms, will be indicated. These results help to clarify the role that has been played by activation-energy asymptotics and to point toward future trends in asymptotic methods for flames.

10:30 am	**Coffee break**	Reception Room EE/CS 3-176

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IMA SEMINAR ON INDUSTRIAL PROBLEMS

11:15 am	**J. Allen Cox** Honeywell	Applications and modeling of diffractive optical elements

Abstract: Diffractive optics technology provides a new approach to optical design and fabrication using computer-aided design tools and integrated circuit manufacturing methods. With this approach, one creates an efficient holographic element in the form of a surface relief profile etched into an optical substrate. The appropriate interference fringe pattern is created on the surface with high resolution lithography.

An accurate mathematical model of diffractive elements is essential for design development and performance prediction. A rigorous mathematical description is provided by solutions to Maxwell's equations in R^3 using the surface relief profile with complex optical constants as the boundary condition. Several groups have examined this problem in detail for the case of singly or doubly periodic surface patterns.

Applications and modeling of periodic devices will first be reviewed. The need to model more complex contours and to extend the theory to include nonlinear coupling is then discussed with additional examples.

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2:00 pm	**A.N. Sharkovsky** Ukraine Academie of Science	Space-time chaos and self-stochasticity in deterministic systems

Abstract: The phenomenon, which we call self-stochasticity, can take place in mathematical patterns of deterministic distributed systems. It consists of the fact that the system behavior is described exactly by stochastic laws if time is large asymptotically.

CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 1989-90 PROGRAM YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
H. Scott Dumas	SUNY, Albany
Mohamed Elbialy	University of Cincinnati
Michael S. Jolly	Princeton University

Maciej Krupa	University of Houston
Stephane Lauderich	Boston University
Debra Lewis	Cornell University
Kening Lu	Georgia Institute of Technology
Mary Silber	UC, Berkeley
Matthew W. Stafford	Loyola University
Mary Lou Zeeman	UC, Berkeley

LONG-TERM VISITORS IN RESIDENCE
One Month or Longer

Todd Arbogast	University of Houston	summer & fall
Rutherford Aris	University of Minnesota	fall
Donald Aronson	University of Minnesota	
A.V. Babin	Moscow Inst. of Transportation	Oct. - Dec.
Pavol Brunovský	Comenius University, Bratislava	Sep 11 - Dec 11
Shui-Nee Chow	Georgia Tech	Sep 15 - Jun 15
Bruce Clarke	University of Alberta	Oct 16 - Nov 17
Edward N. Dancer	University of New England, Aust.	Sep 1 - Nov 30
Jack D. Dockery	Montana State University	Sep 1 - Dec 15
J.W. Dold	University of Bristol	Nov 1 - Nov 30
Avner Friedman	University of Minnesota	
Alain Genestier		Nov 1 - Nov 30
Christophe Gole	Boston University	Sep 8 - Jun 15
Martin Golubitsky	University of Houston	Sep 4-15, 4 wks. in Oct/Nov
Betsy Gotler	University of Minnesota	
Leon Green	University of Minnesota	
Jack K. Hale	Georgia Tech	Oct 15-Dec 31; Mar 12-Mar 16, Mar 19-Apr 13, May 29-Jun 2
Russell Johnson	University of Southern California	Sep 1 - Jun 15
Paula Jossart	University of Minnesota	
Harvey Keynes	University of Minnesota	
Philip Korman	University of Cincinnati	Sep 3 - Dec 15
William Langford	University of Guelph	Sep 4 - Dec 1, spring visit
Cheng-Ming Lee	U. of Wisconsin, Milwaukee	Sep 4 - Dec 15
John Lorentz	University of Minnesota	
Martine Marion	Ecole Centrale de Lyon	Nov 13 - Nov 17, Apr 1 - Jun 15
John Mallet-Paret	Brown University	Sep 10-16, Oct 8-27, other visits
Larry Markus	University of Minnesota	
Hiroshi Matano	University of Tokyo	Sep 4 - Apr 9
Richard McGehee	University of Minnesota	
Kenneth Meyer	University of Cincinnati	Sep 1 - Jun 1
Milan Miklavcic	Michigan State University	Sep 1 - Mar 15
Willard Miller	University of Minnesota	
Konstantine Mischaikow	Georgia Institute of Technology	Sep 1 - Nov 30
Richard Moeckel	University of Minnesota	
Hieu Nguyen	University of Minnesota	
Basil Nicolaenko	Arizona State University	Apr 15 - Jun 30
Yasumasa Nishiura	Hiroshima University	Oct 10 - Nov 20
Peter Olver	University of Minnesota	
Hans G. Othmer	University of Utah	Oct 2 - Oct 31
Peter Poláčik	Comenius Univ., Bratislava	Sep 4 - Dec 1
Geneviève Raugel	Université d'Orsay	Sep 15 - Dec 15 & 1 mo, spring
James Reineck	SUNY, Buffalo	Sep 1 - Jun 1

Carlos Rocha	Lisbon	Sep 1 - Nov 30
George R. Sell	University of Minnesota	
Pat Sethna	University of Minnesota	
A.N. Sharkovsky	Ukrainian Acad. of Sciences	Oct 15 - Nov 15
Yasutaka Sibuya	University of Minnesota	
Peter Szmolyan	Tech. U. Vienna	Sep 5 - Jun 30
Long-yi Tsai	Nat. Chengchi University	Sep 1 - Feb 28
M. I. Vishik	Moscow State University	Oct 5 - Nov 17
Christopher Weber	University of Minnesota	
Ying-Fei Yi	University of Southern California	Sep 5 - Jun 15
David Yuen	University of Minnesota	

SHORT TERM AND WORKSHOP VISITORS IN RESIDENCE

Joel Avrin	University of North Carolina	Oct 15-22, Nov 12-17
Mel Baer	Sandia Nat. Labs.	Nov 13 - Nov 17
Jerrold Bebernes	University of Colorado	Nov 13 - Nov 17
Michael Booty	Southern Methodist University	Nov 11 - Nov 17
John D. Buckmaster	University of Illinois	Nov 15 - Nov 17
Chao-Nien Chen	Indiana University	Nov 11 - Nov 19
Michel Chipot	U. de Metz	Nov 13 - Nov 17
J. Allen Cox	Honeywell	Nov 17 - Nov 17
Paul Fife	University of Utah	Sep 10- 15, Nov 13-17
Michael Frankel	IUPUI	Nov 15 - Nov 19
Michael Gorman	U. of Houston-U. Park	Nov 12 - Nov 17
Stuart Hastings	University of Pittsburgh	Nov 13 - Nov 17
Ash Kapila	RPI	Nov 12 - Nov 17
David R. Kassoy	University of Colorado	Nov 13 - Nov 17
Rupert Klein	Princeton University	Nov 13 - Nov 17
Amable Liñán	Madrid	Nov 13 - Nov 17
David Logan	University of Nebraska	Nov 8 - Nov 17
Andrew Majda	Princeton University	Nov 13 - Nov 17
Stephen B. Margolis	Sandia Nat. Labs.	Nov 13 - Nov 17
Bernard Matkowsky	Northwestern University	Nov 13 - Nov 16
Ralph Menikoff	Los Alamos Nat. Labs.	Nov 13 - Nov 17
Rochejoffre, Jean-Michel	U. Paris VI	Nov 12 - Nov 19
Victor Roytburd	Rensselaer Polytechnic Inst	Nov 13 - Nov 17
D. Scott Stewart	U. of Illinois-Urbana	Nov 13 - Nov 17
William Troy	University of Pittsburgh	Nov 13 - Nov 17
David Wagner	University of Houston	Nov 13 - Nov 17
Forman Williams	UC San Diego	Nov 13 - Nov 17

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IMA NEWSLETTER #148

October 13 - 29, 1989

1989-90 Program
DYNAMICAL SYSTEMS AND THEIR APPLICATIONS

NEWS AND NOTES

Workshop on PATTERNS AND DYNAMICS IN REACTIVE MEDIA

October 16–20, 1989
Organizers: R. Aris, D. Aronson, S.-N. Chow, P. Fife, M. Golubitsky, R. McGehee, G. R. Sell and H. Swinney

The speakers at this workshop will include representatives from chemistry, chemical engineering, and mathematics. The topics from chemistry to be covered are: Bursting, complex chemistry, electrochemical reactors, pattern formation, stability of fronts, stirred tanks dynamics, and tubular dynamics. The mathematical topics are: Bifurcation theory, connection theory, forced oscillations, invariant manifolds, reaction diffusion equations, renormalization methods, singular perturbations, spectral issues, and symmetries.

The lectures will be held in Conference Hall 3-180 on the entry floor of the new Electrical Engineering/Computer Science Building. This building is located on the corner of Washington Avenue and Union Street, a block from the IMA Main Office. The conference hall is on the Ethernet and has a projection system for display of computer output.

The detailed Workshop schedule, and the regular IMA program, can be found in the pages to follow.

PARTICIPATING INSTITUTIONS:Georgia Institute of Technology, Indiana University, Iowa State University, Michigan State University, Northern Illinois University, Northwestern University, Ohio State University, Purdue University, University of Chicago, University of Cincinnati, University of Houston, University of Illinois (Chicago), University of Illinois (Urbana), University of Iowa, University of Michigan, University of Minnesota, University of Notre Dame, University of Pittsburgh, Wayne State University
PARTICIPATING CORPORATIONS:Bellcore, Cray Research, Eastman Kodak, General Motors, Honeywell, IBM, 3M, UNISYS

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1:30 pm	**Ken Keller** University of Minnesota	Introduction
1:30 pm	**Harmon Ray** University of Wisconsin	Some adventures in polymerization reaction engineering
2:30 pm		Break
3:00 pm	**Thomas Clayton** Classics, University of Minnesota	Hypertextuality and Shakespear's most artistic success

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Workshop on PATTERNS AND DYNAMICS IN REACTIVE MEDIA

October 16–20, 1989

Organizers: R. Aris, D. Aronson, S.-N. Chow, P. Fife, M. Golubitsky, R. McGehee, G. R. Sell and H. Swinney

Monday, October 16

The scheduled talks today are in Conference Hall EE/CS 3-180

9:00 am	**Registration and coffee hour**	Reception Room EE/CS 3-176
9:30 am	**Martin Feinberg** University of Rochester	Some recent results in chemical reaction network theory

Abstract: The aim of chemical reaction network theory is to draw connections between reaction network structure and qualitative properties of the corresponding differential equations. Some recent results will be discussed, in particular those relating to the possibility of multiple steady states in complex isothermal CSTRs, to mechanism discrimination in heterogeneous catalysis, and to the possibility of travelling composition waves on isothermal catalyst surfaces.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**John Guckenheimer** Cornell University	Computational tools for multiparameter bifurcation problems

Abstract: This lecture will discuss the numerical calculation of bifurcation diagrams for multiparameter bifurcation problems. Emphasis will be placed upon global bifurcations accessible only through long time integrations or iterations of dynamical systems. An interactive computational environment for studying these problems will be described. Examples drawn from studies of coupled oscillators and the Hodgkin-Huxley equations will be described.

2:00 pm	**Stephen Scott** University of Leeds	The influence of self-heating on isothermal chemical oscillators

Abstract: Chemical reactions frequently evolve heat and proceed at rates that are sensitive functions of the local temperature. The effects of coupling self-heating with chemical feedback are investigated through

an extension of the cubic autocatalator model for isothermal oscillations. Period-doubling routes to chaos, mixed-mode oscillations and thermal explosions are features of the extended model. Similar responses are also found with a linear, chemical feedback step.

4:00 pm	**Vincent Hall 502** (The IMA Lounge)	IMA Tea (and more!)

Tuesday, October 17

The scheduled talks today are in Conference Hall EE/CS 3-180

9:30 am	**Yannis G. Kevrekides** Princeton University	Scaling laws and pattern formation in coupled reaction-diffusion systems

Abstract: Coupled reaction-diffusion equations are known to exhibit a wealth of multiple coexisting stationary solution patterns as the characteristic length of the system grows. We describe and implement a technique which allows us, by studying only stationary solution branches at small system lengths, to predict the complex bifurcation structure occurring at large system lengths without actually computing this structure. This technique is applicable to arbitrary isothermal or nonisothermal systems of coupled reaction-diffusion equations with periodic or no-flux boundary conditions. We use a number of standard literature examples (like the Brussellator, and the Catalano-Eilbeck scheme) to demonstrate the use of this technique. This provides a compact way of describing and comparing stationary pattern formation in a large class of systems, extending beyond coupled reaction-diffusion equations. We demonstrate this by comparing stationary patterns for our test reaction-diffusion systems with patterns in thin film flow. We also discuss some computational aspects of performing these bifurcation calculations, in particular the use of approximate inertial forms.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	***Gregory S. Yablonskii*** Tubinskii Complex Dept.	A kinetic polynomial: New concept of chemical kinetics

Abstract: We found for linear mechanisms, by methods of graph theory, a structured form of kinetic equation. In the general case a system of pseudo-steady-state equations for catalytic reactions can always be reduced to a polynomial in terms of the steady-state reaction rate, this is called a kinetic polynomial. The coefficients of this polynomial are polynomials in the parameters of the elementary reaction rates. The form of lowest coefficient of the polynomial ensures the thermodynamic validity of this form of kinetic model. This leads to a standard form of the dynamics of reaction and is used for the analysis of hysteresis and bifurcations.

Joint Chemical Engineering Colloquium/IMA Talk

1:15 pm	**Dan Luss** University of Houston	Spatial and spatiotemporal structures on catalytic surfaces

Abstract: Symmetry breaking can lead to the occurrence of structured solutions in many systems. For example, when a chemical reaction is carried out on heated catalytic ribbons or unheated catalytic disks nonuniform temperature patterns and waves are observed. This can lead to rather intricate dependence of the overall rate on the operation conditions and to a disguise of the intrinsic kinetic behavior.

Simplified mathematical models are used to study the features of the system. They predict rather intricate dynamic behavior and point out the need to gain a better understanding and prediction of mode interaction in diffusion reaction problems.

3:00 pm	**J.L. Hudson** University of Virginia	Dynamics of some electrochemical reactions

Abstract: Experiments on a few electrochemical reactions are discussed. Time series of either current or voltage, obtained under potentiostatic or galvanostatic conditions respectively, are presented and characterized. We first show some examples of dynamic behavior such as chaos, quasiperiodicity, and period doubling of tori obtained during the electrodissolution of copper. Some apparent higher order chaos is then discussed.

Finally, we discuss briefly some dynamics of an electrodeposition reaction and the electrocatalytic reduction of hydrogen peroxide.

Wednesday, October 18

All scheduled talks today are in Conference Hall EE/CS 3-180

9:30 pm	**Christopher Jones** University of Maryland	Tracking invariant manifolds with differential forms.

Abstract: To find heteroclinic or homoclinic orbits in a fast-slow system requires understanding how the unstable (or stable) manifold of a critical point behaves as it passes near a slow manifold of the system. In joint work with Nancy Kopell, we use the induced flow on the space of exterior forms to determine the transfer of information that occurs during this passage. Using the product of this analysis and transversality information from the fast flow, the relevant orbits can be determined. For the case of travelling wave solutions of some PDE the information is also relevant to stability.

10:30 am	**Coffee Break**	Reception Room EE/CS 3-176
11:00 am	**M. I. Vishik** Moscow State University	Uniform asymptotics of solutions of evolution equations depending on parameters

Abstract: Trajectories of evolutionary equations (for example reaction diffusion equations, damped hyperbolic equations) regularly or singularly depending on a parameter are considered. The principal term of asymptotic behaviour for all $t \geq 0$ with respect to the parameter is constructed. The asymptotic trajectories are piecewise continuous functions of t and except for the first continuous piece they lie on unstable manifolds of the equilibria. These manifolds correspond to the limit value of the parameter. The estimation of the difference between the trajectories and their asymptotics is uniform with respect to t and the initial data.

2:00 pm	**Joel Smoller** University of Michigan	Bifurcation from symmetry

Abstract: We give a new general bifurcation theorem in the presence of symmetry and apply it to find asymmetric (non-radial) solutions of

$$\Delta u + f(u) = 0 \quad \text{on} \quad \Omega = n\text{-ball}$$

$$\alpha u - \beta \frac{du}{du} = 0 \quad \text{on} \quad \partial\Omega,$$

having various symmetry properties.

3:00 pm	**Ehud Meron** Weizmann Institute	Wavefront interactions and their effects on pattern formation in excitable media

Abstract: The nonlinear interactions of solitary wavefronts in excitable media are determined by the manner of recovery to the rest state. The distance between a pair of wavefronts tends to lock at one of countably many possible values in the case of oscillatory recovery, while it increases indefinitely when the recovery is monotonic, We derive these results from the basic reaction diffusion equations and study the implications on pattern formation in one and two space dimensions. In particular we demonstrate how spatiotemporal complexity may arise in one dimension, and discuss possible consequences of the interplay between wavefront-interactions and curvature in two dimensions.

Thursday, October 19

All talks today, except the Colloquium, are in Conference Hall EE/CS 3-180

9:30 am	**Yasumasa Nishiura** Hiroshima University	Singular limit approach to the existence of curved fronts in phase field model

Abstract: We consider the instability of planar solidification wave advancing in a supercooled liquid in a channel. A phase field model is employed in which surface tension and dynamic cooling effects are automatically incorporated. The interface described by this model has finite thickness of order E, where E is a small microscopic parameter. Using, what is called, the SLEP method, we obtain a bifurcation of curved fronts from planar one for small positive E when the channel width and latent heat paramoters vary. This could be regarded as an onset of more complicated patterns such as dendrite.

10:30 am	**Coffee break**	Reception Room EE/CS 3-176
11:00 am	**Robert Franzosa** University of Maine	A Computational approach to connection matrices and the algebraic transition theory

Abstract: A discussion of the connection matrix theory from a computational viewpoint, and recent results about detecting connections via the algebraic transition theory.

2:00 pm	**W. W. Farr** Worchester Polytechnic University	Rotating chemical waves in the Gray-Scott model

Abstract: We consider a model set of reaction-diffusion equations defined on a circle and investigate the stability of rotating wave solutions formed via Hopf bifurcations which break the circular (O(2)) symmetry. Stable rotating waves have been observed in experiments with the Belousov-Zhabotinskii reaction. Using hybrid numerical/analytical techniques we perform center manifold/normal form reductions to analyze symmetry-breaking Hopf bifurcations, degenerate Hopf bifurcations, and Hopf-Hopf mode interactions. We find that the behavior of this model can be very complex, including two and three frequency motions, but that stable rotating waves exist over broad ranges of parameter values. (Joint work with Martin Golubitsky.)

Joint School of Mathematics Colloquium/IMA talk

3:15 pm	**Harry Swinney** University of Texas at Austin	Experiments on bifurcations in chemical spatiotemporal patterns

Abstract: Experiments have been conducted on several different spatially extended one-and two- dimensional reactors that have been designed for studies of bifurcations in reaction-diffusion systems. The reactors can be maintained indefinitely in well-defined nonequilibrium states. The sequences of bifurcation that are observed as a function of a control parameter (chemical concentration) are in qualitative accord with those found for a simple reaction-diffusion model system with two species. The model provides insight into the observed behavior.

The Colloquium will take place in Vincent Hall 16
Tea will be served at 2:55 pm in Vincent Hall 120.

Friday, October 20

All scheduled talks today are in Conference Hall EE/CS 3-180

9:30 am	**Jeffrey Derby** University of Minnesota	Dynamics in materials processing: Outstanding problems in melt crystal growth

Abstract: We are entering an era in which chemical engineers and materials scientists are attempting to control structure in solids at the molecular level. This control requires detailed understanding of the dynamics of the processes which are used to produce these materials. This seminar will address some outstanding issues in understanding the growth of large-dimension laser host crystals. We will present recent results from mathematical models of the Czochralski crystal growth process and emphasize current inadequacies in our methods for analysis of the dynamical behavior of these systems.

10:30 am	**Coffee break**	Reception Room EE/CS 3-176
11:00 am	**Jack K. Hale** Georgia Institute of Technology/IMA	Effect of domain variation on dynamics

Abstract: For reaction-diffusion systems (regular or irregular) we discuss how variations in the shape of the domain can influence the dynamics. Particular attention will be devoted to the case where the dimension of the perturbed domain is larger than the dimension of the unperturbed one at some points.

2:00 pm **Hiroshi Matano** — Blow up in nonlinear diffusion equations
University of Tokyo/IMA

Abstract: Much progress has been made in the past few years in the study of profile of solutions at the blow-up time. I will talk about the recent developments in this area. Related problems such as "quenching" will also be discussed.

Special Lecture-Demonstration

3:30 pm **David Lomen** — Computer Enhanced Education at the University of Arizona
University of Arizona

Abstract: Our overriding principle has been to use computers only when they improve the quality of education, We have identified a number of ways in which computers may be used to advantage for instructional purposes:

1. As an aid to the instructor during class,
2. As an aid to students in problem solving,
3. To encourage and facilitate student exploration,
4. To diagnose the areas in which a student needs remediation before proceeding with a course.

We will elaborate on these points and demonstrate some of the software we have developed. The focus will be on the first two years of college mathematics.

Tuesday, October 24

SEMINAR IN { Reaction Dynamics
Vincent Hall 570

11:15 am **Peter Poláčik** — Simple and complicated dynamics in scalar semilinear parabolic equations
Comenius Univ., Bratislava/IMA

Abstract: The dynamics of scalar semilinear parabolic equations of second order will be discussed. Several results will be presented showing that while the typical behavior of trajectories is very simple (monotone convergence to equilibria), still one can find equations where complicated dynamics occurs.

SEMINAR IN { Mathematics
Physics
Vincent Hall 570

2:15 pm **Debra Lewis** — Nonlinear stability of homogeneous elastic bodies
Cornell/IMA

Abstract: A homogeneous elastic body (aka pseudo-rigid body) is an elastic body for which the deformation gradient is constant throughout the body. The configuration space of all such bodies can be identified with the matrix group GL(3). We consider the nonlinear stability of rotating relative equilibria within this class of elastic bodies. By means of the reduced energy momentum method, we obtain explicit stability conditions for several classes of materials, including Ciarlet-Geymonet and Mooney-Rivlin materials.

SEMINAR ON MATHEMATICAL VISUALIZATION

3:30 pm **Igor Rivin** — MATHEMATICA and graphics
Wolfram Research

This talk will be held in Vincent Hall 16

Wednesday, October 25

SEMINAR IN { Reaction Dynamics, Vincent Hall 570

11:15 am	**Carlos Rocha** Lisbon	Attractors for the scalar bistable reaction diffusion equation

Abstract: We consider the problem of classification for the attractors of the equation $u_t = u_{xx} + f(u)$, $x \in [0,1]$ with Neumann boundary conditions and compare with the cases where $f = f(x,u)$ and $f = f(x,u,u_x)$.

IMA POSTDOC SEMINAR

3:10 pm	**Mary Lou Zeeman** MIT/IMA	An introduction to monotone systems

Abstract: We shall discuss, at an introductory level, some of the ideas, results and techniques of monotone systems - mainly those developed by M.W. Hirsch in his series of papers: Systems of Differential Equations that are Competitive or Cooperative I - VI.

Thursday, October 26

SEMINAR ON INDUSTRIAL PROBLEMS: UNDERGRADUATE COMPONENT

10:10 am	**Walter Littman** University of Minnesota	Open only to selected undergraduate participants

Background: A group of a half dozen undergraduates are meeting on a regular basis with Professor W. Littman in Vincent Hall 570 in conjunction with the Industrial Problem Seminar. One of the aims of this activity is to bridge the gap between the knowledge acquired in regular course work and the know-how necessary to attack problems as they actually appear in industry. Another aim is to channel the enthusiasm for computing that many students have into productive scientific channels.

SEMINAR IN { Dynamics and Mechanics, Vincent Hall 570

11:15 am	**Debra Lewis** Cornell/IMA	The reduced energy-momentum method: Nonlinear stability of simple mechanical systems

Abstract: A simple mechanical system consists of a canonical phase space, with configuration and momentum variables (q,p), a Lie group G which acts on the phase space by canonical transformations, and a G-invariant Hamiltonian $H(q,p) = V(q) + 1/2|p|^2$. Many classical mechanical systems fall into this category. The reduced energy-momentum method is an energy method for the nonlinear stability analysis of such systems. This method has a number of computational advantages, including the following: the energy functional (Smale's amended potential) is defined on the configuration space, rather than the full phase space; the configuration variations are decomposed into infinitesimal group motions and 'internal' variations, which decouple with respect to the energy functional; all momentum constraints are automatically incorporated in the variations, resulting in apparently sharp stability conditions.

SEMINAR ON FLOER HOMOLOGY

2:00 pm		Richard Moeckel, Organizer

Abstract: The goal of this SEMINAR is to understand Floer's approach to the problem of finding periodic orbits of Hamiltonian systems. We will work through several survey papers as well as some of Floer's. The

SEMINAR will meet weekly as long as there is sufficient interest. Details about each session will be provided in due course.

The SEMINAR meets in Vincent Hall 570.

Friday, October 27

SEMINAR ON INDUSTRIAL PROBLEMS

11:15 am	**Carl A. Nelson** Honeywell	Fundamental problems in the theory of shaped-charge jets

Abstract: A shaped charge is a high-explosive device which implodes a metal-lined cavity and produces a high velocity jet. A brief overview of shaped-charge phenomena will be given. this will be followed by a discussion of the theory of Euler flows and their application to jets, and the complications arising from compressibility, unsteady flow, etc. Finally, some unsolved problems of practical interest will be presented.

The SEMINAR meets in Vincent Hall 570.

SPECIAL DEMONSTRATION

12:30 pm	**E.J. Doedel** Concordia University, Montreal	Tutorial on AUTO

Abstract: Doedel, the author of AUTO, will give an AUTO tutorial in the IMA Seminar Room (VH 570). AUTO is a state of the art program for tracing bifurcations. For more (advance) information, see Don Aronson. AUTO is available on the Apollo network.

SPECIAL LECTURE

3:15 pm	**E.J. Doedel** Concordia University, Montreal	Coupled Josephson Junctions: The video!

The SPECIAL LECTURE will be in Vincent Hall 570.

CURRENT IMA PARTICIPANTS

POSTDOCTORAL MEMBERS FOR 1989-90 PROGRAM YEAR

NAME	PREVIOUS/PRESENT INSTITUTION
H. Scott Dumas	SUNY, Albany
Mohamed Elbialy	University of Cincinnati
Michael S. Jolly	Princeton University
Maciej Krupa	University of Houston
Stephane Laederich	Boston University
Debra Lewis	Cornell University
Kening Lu	Georgia Institute of Technology
Mary Silber	UC, Berkeley
Matthew W. Stafford	Loyola University
Mary Lou Zeeman	UC, Berkeley

LONG-TERM VISITORS IN RESIDENCE
One Month or Longer

Todd Arbogast	University of Houston	summer & fall
Rutherford Aris	University of Minnesota	fall
Donald Aronson	University of Minnesota	
A.V. Babin	Moscow Inst. of Transportation	fall visit
Pavol Brunovský	U. Komenskeho, Czechoslovakia	Sep 11 - Dec 11

Shui-Nee Chow	Georgia Tech	Sep 15 - Jun 15
Bruce Clarke	University of Alberta	Oct 16 - Nov 17
Edward N. Dancer	University of New England, Aust.	Sep 1 - Nov 30
Jack D. Dockery	Montana State University	Sep 1 - Dec 15
Robert Ellis	University of Minnesota	
Avner Friedman	University of Minnesota	
Christophe Gole	Boston University	Sep 8 - Jun 15
Martin Golubitsky	University of Houston	Sep 4-15, 4 wks. in Oct/Nov
Betsy Gotler	University of Minnesota	
Leon Green	University of Minnesota	
John Guckenheimer	Cornell University	Oct 16-20, May 15 - Jun 15
Jack K. Hale	Georgia Tech	Oct 15-Dec 31; Mar 12-Mar 16, Mar 19-Apr 13, May 29-Jun 2
Russell Johnson	University of Southern California	Sep 1 - Jun 15
Paula Jossart	University of Minnesota	
Yannis Kevrekidis	Princeton University	Oct 12-22, May 15-Jun 15
Klaus Kirchgässner	Univ Stuttgart	Apr 1 - Apr 30
Nancy Kopell	Boston University	Oct 17-22, Mar 26 - Apr 13
Philip Korman	University of Cincinnati	Sep 3 - Dec 15
William Langford	University of Guelph	Sep 4 - Dec 1, spring visit
Cheng-Ming Lee	U. of Wisconsin, Milwaukee	Sep 4 - Dec 15
John Lorentz	University of Minnesota	
John Mallet-Paret	Brown University	Sep 10-16, Oct 8-27,other visits
Larry Markus	University of Minnesota	
Hiroshi Matano	University of Tokyo	Sep 4 - Apr 9
Richard McGehee	University of Minnesota	
Kenneth Meyer	University of Cincinnati	Sep 1 - Jun 1
Milan Miklavcic	Michigan State University	Sep 1 - Mar 15
Willard Miller	University of Minnesota	
Konstantine Mischaikow	Georgia Institute of Technology	Sep 1 - Nov 30
Richard Moeckel	University of Minnesota	
Hieu Nguyen	University of Minnesota	
Yasumasa Nishiura	Kyoto Sangyo University	Oct 10 - Nov 20
Peter Olver	University of Minnesota	
Hans G. Othmer	University of Utah	Oct 2 - Oct 31
Peter Poláčik	Comenius Univ., Bratislava	Sep 4 - Dec 1
Geneviève Raugel	Palaiseau Ecole Polytech	Sep 15 - Dec 15 & 1 mo, spring
James Reineck*	SUNY, Buffalo	Sep 1 - Jun 1
Mark Roberts	University of Warwick	Oct 16-20, 1 month winter
Carlos Rocha	Lisbon	Sep 1 - Nov 30
Stephen Scott	University of Leeds	Sep 25 - Oct 21
George R. Sell	University of Minnesota	
Pat Sethna	University of Minnesota	
A.N. Sharkovsky	Ukrainian Acad. of Sciences	Oct 15 - Nov 15
Yasutaka Sibuya	University of Minnesota	
Peter Szmolyan	Tech. U. Vienna	Sep 5 - Jun 30
Long-yi Tsai	Nat. Chengchi University	Sep 1 - Feb 28
M. I. Vishik	Moscow State University	Oct 5 - Nov 17
Christopher Weber	University of Minnesota	
Ying-Fei Yi	University of Southern California	Sep 5 - Jun 15
David Yuen	University of Minnesota	

SHORT TERM AND WORKSHOP VISITORS IN RESIDENCE

Nick Alikakos	University of Tennessee	Oct 16 - Oct 20
Neal Amundson	University of Houston	Oct 16 - Oct 20
Jose Arrieta	Georgia Institute of Technology	Oct 16 - Oct 20
Joel Avrin	University of North Carolina	Oct 15-22, Nov 12-17
V. Balakotaiah	University of Houston	Oct 16 - Oct 20
Peter Bates	Brigham Young University	Oct 16 - Oct 20
Jeffrey Derby	University of Minnesota	Oct 18 - Oct 20
W.W. Farr	Worchester Polytechnic University	Oct 18 - Oct 22
Martin Feinberg	University of Rochester	Oct 12 - Oct 18
Robert Franzosa	University of Maine	Oct 16 - Oct 20
Mark J. Friedman	University of Alabama	Sep 4-17, Oct 15-22
George Fusco	Rome	Oct 15 - Oct 20
John Guckenheimer	Cornell University	Oct 16 - Oct 20
Jack Hudson	University of Virginia	Oct 16 - Oct 21
Christopher Jones	University of Maryland	Oct 17 - Oct 20
Peter Knabner	U. Augsburg	Oct 9 - Oct 22
Anthony Leung	University of Cincinnati	Oct 16 - Oct 20
Daniel Luss	University of Houston	Oct 16 - Oct 20
Ehud Meron	Columbia/Weizmann Inst.	Oct 8 - Oct 20
Carl Nelson	Honeywell	Oct 27 - Oct 27
Bruce Peckham	Boston University	Oct 14-22, Mar 4-17
R. Mark Roberts	University of Warwick	Oct 15 - Oct 27
George Seifert	Iowa State University	Oct 19 - Oct 20
Joel Smoller	University of Michigan	Oct 17 - Oct 20
Harry Swinney	University of Texas	Oct 16 - Oct 20
David Terman	Ohio State University	Oct 14-20, Nov 13-19
G.S. Yablonskii	Tubinskii Complex Dept.	Sep 30 - Oct 21